

# Chapter 08

## Lecture Outline\*

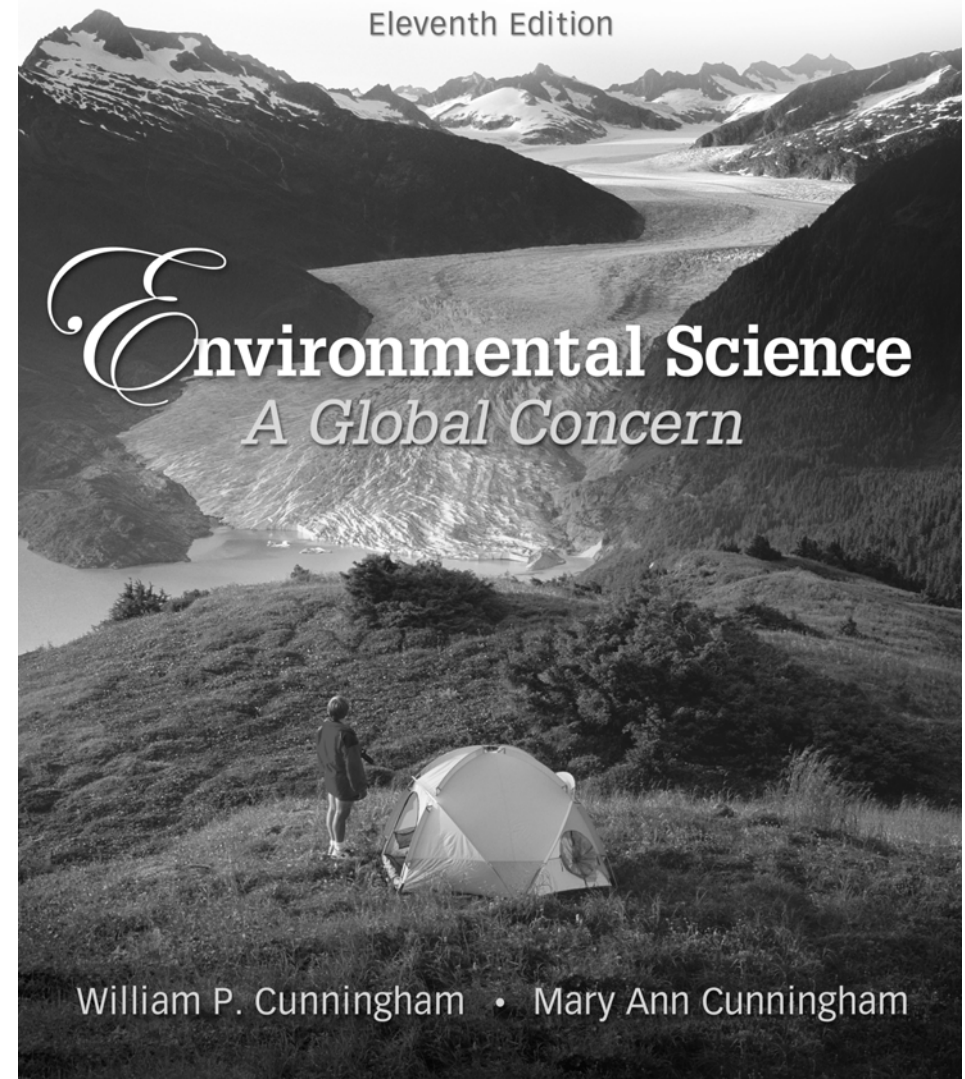
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# Environmental Health and Toxicology

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# Outline

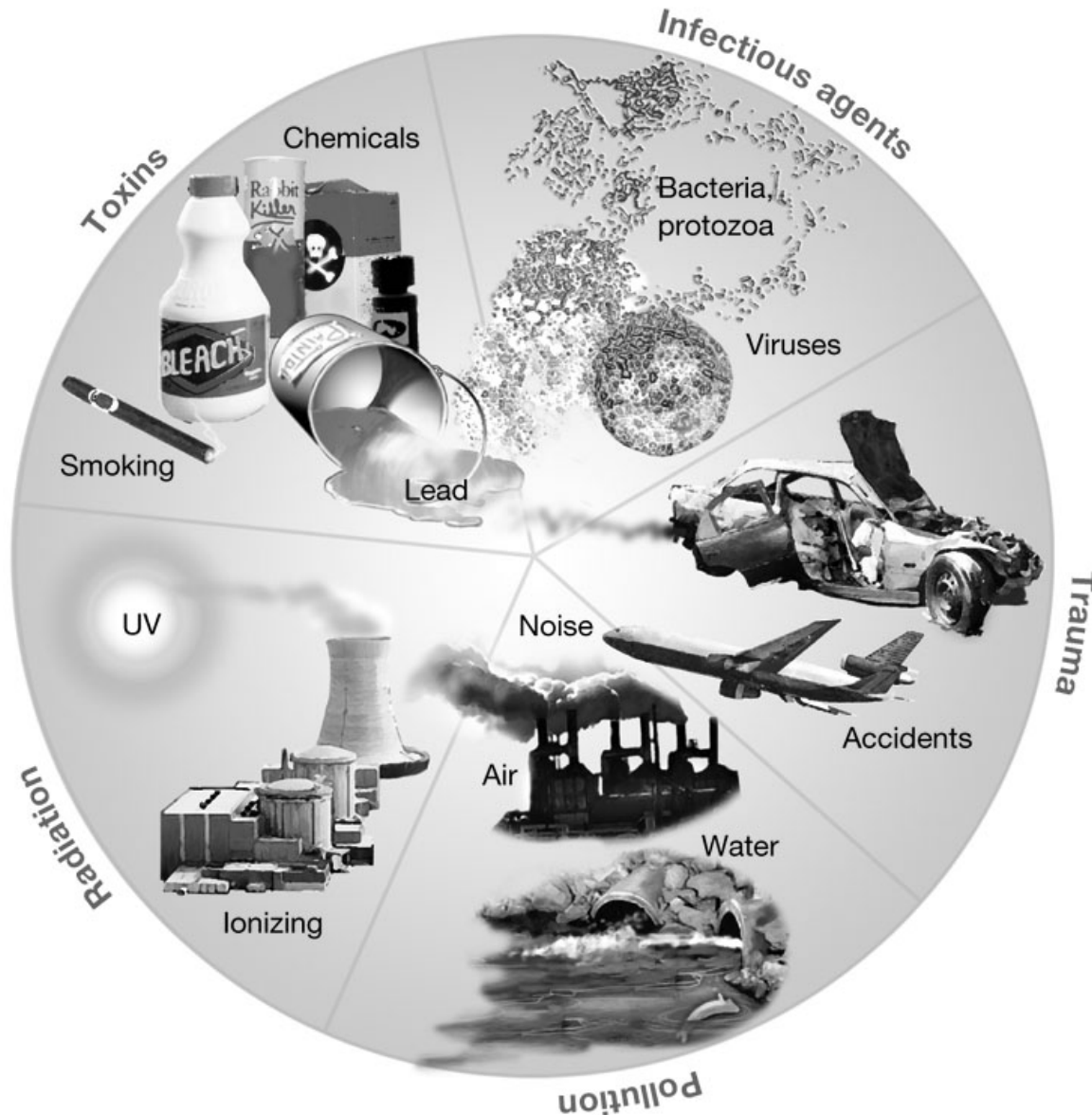
- Environmental Health
  - ❖ Infectious and Emergent Diseases
  - ❖ Antibiotics and Pesticide Resistance
- Toxicology
- Movement, Distribution, and Fate of Toxins
- Minimizing Toxic Effects
- Measuring Toxicity
- Risk Assessment
- Establishing Health Policy

# Environmental Health

- Health - a state of complete physical, mental, and social well-being
- Disease - an abnormal change in the body's condition that impairs physical or psychological function
  - ❖ Diet and nutrition, infectious agents, toxic chemicals, genetics, trauma and psychological stress all play roles in morbidity (illness) and mortality (death).

# Environmental Health Risks

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# Global Disease Burden

- Life expectancy increasing as infant mortality decreases.
- Disability-adjusted life years (DALYs) - combine premature deaths and loss of healthy life resulting from illness or disability
- Chronic conditions account for 60% of premature deaths and 50% of diseases.
  - ❖ By 2020, heart disease may become leading source of disability and disease worldwide. Global cancer rates will increase by 50%.

# Global Disease Burden

- Diabetes is on the increase. One-third of children born in North America today will develop diabetes in their lifetime due to poor diet and little exercise.
- WHO projects that psychological conditions could increase their share of the global disease burden from 10% currently to 15%.
  - ❖ Depression will be the second largest cause of all years lived with disability.
- Tobacco related lung diseases are increasing. Biggest single cause of death worldwide.

# Causes of Global Disease Burden

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**TABLE 8.1**

## Leading Causes of Global Disease Burden

Rank	1990	Rank	2020
1	Pneumonia	1	Heart disease
2	Diarrhea	2	Depression
3	Perinatal conditions	3	Traffic accidents
4	Depression	4	Stroke
5	Heart disease	5	Chronic lung disease
6	Stroke	6	Pneumonia
7	Tuberculosis	7	Tuberculosis
8	Measles	8	War
9	Traffic accidents	9	Diarrhea
10	Birth defects	10	HIV/AIDS
11	Chronic lung disease	11	Perinatal conditions
12	Malaria	12	Violence
13	Falls	13	Birth defects
14	Iron anemia	14	Self-inflicted injuries
15	Malnutrition	15	Respiratory cancer

Source: World Health Organization, 2002.



# Infectious Diseases

- Communicable diseases are still responsible for about 1/3 of all disease-related deaths.
  - Majority in countries with poor nutrition, sanitation, and vaccination
    - Malaria is a major disease in tropical areas. Two million people die each year.
- Better nutrition, clean water, improved sanitation and inoculation of children could eliminate most of the deaths.

# Pathogens

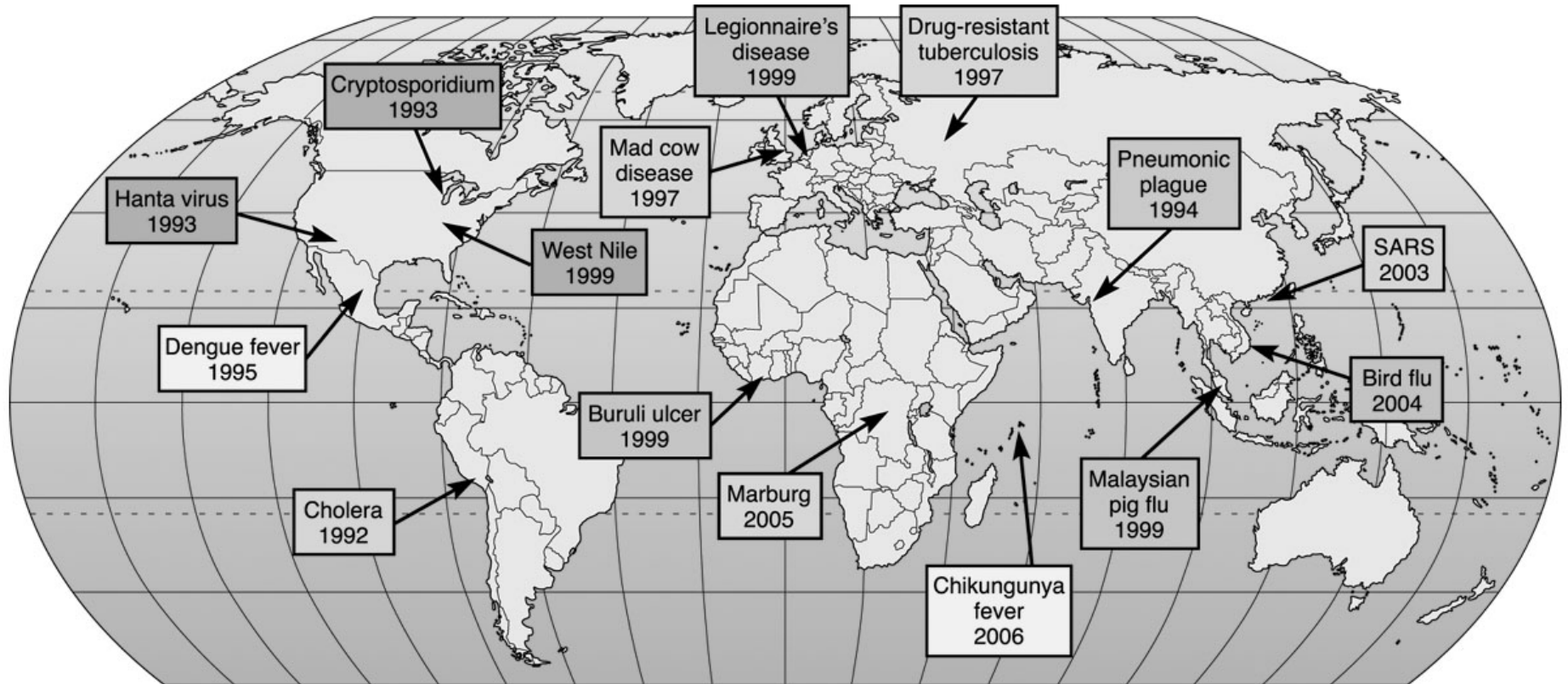
- Pathogens are disease-causing organisms. They include:
  - ❖ Viruses
  - ❖ Bacteria
  - ❖ Protozoans
  - ❖ Parasitic worms
  - ❖ Flukes
- Greatest loss of life in a single year from a pathogen was in 1918 when the flu epidemic killed 50 to 100 million people worldwide. Today we are concerned that bird flu might cause an even larger outbreak.

# Emergent Diseases

- An emergent disease is one never known before, or one which has been absent for at least 20 years.
  - ❖ Bird flu
  - ❖ Ebola fever
  - ❖ HIV
- Growing human populations push into remote areas where they encounter pathogens.
- Air travel makes it possible to spread emergent diseases around the globe quickly.
  - ❖ West Nile virus was introduced into North America in 1999, and is now found everywhere in the lower 48 states.

# Recent Human Disease Outbreaks

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# Conservation Medicine

- Ecological diseases - animal epidemics
  - ❖ A viral hemorrhagic disease is killing fish in the Great Lakes; introduced through ballast.
  - ❖ California sea lions have herpes 1 virus spread to them from human sewage.
  - ❖ An imported fungus is killing oak, redwoods, and Douglas fir trees in California.
  - ❖ Dermo, a parasite of oysters, is spreading rapidly along the east coast due to climate warming.
- Conservation medicine – examines how environmental changes threaten the health of humans and natural communities

# Pesticide Resistance

- The protozoan parasite that causes malaria is now resistant to most antibiotics, while the mosquitoes that transmit it have developed resistance to many insecticides.
  - ❖ Natural selection and the ability of organisms to evolve rapidly
  - ❖ Human tendencies to overuse pesticides speeds up this process.

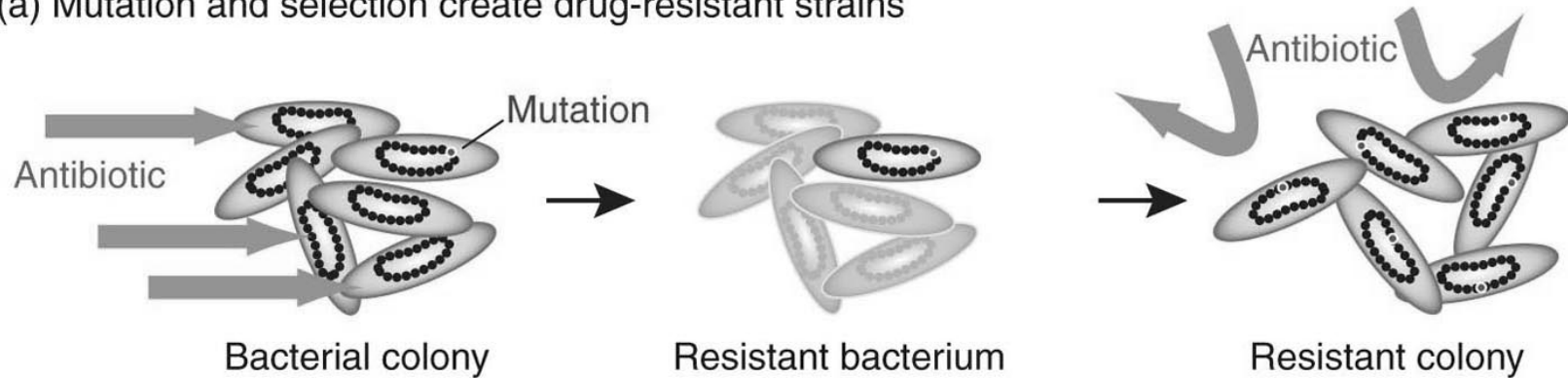
# Antibiotic Resistance

- At least half of the 100 million antibiotic doses prescribed in the U.S. every year are unnecessary or are the wrong drug.
- Many people do not finish the full-course, creating resistant strains of bacteria.
  - ❖ ie. Antibiotic resistant strains of MRSA are spreading through hospitals in the US and China resulting in thousands of deaths.
- Antibiotics are routinely fed to U.S. farm animals to stimulate weight gain. These are excreted in urine and feces, and find their way into surface waters where they create more antibiotic resistance.

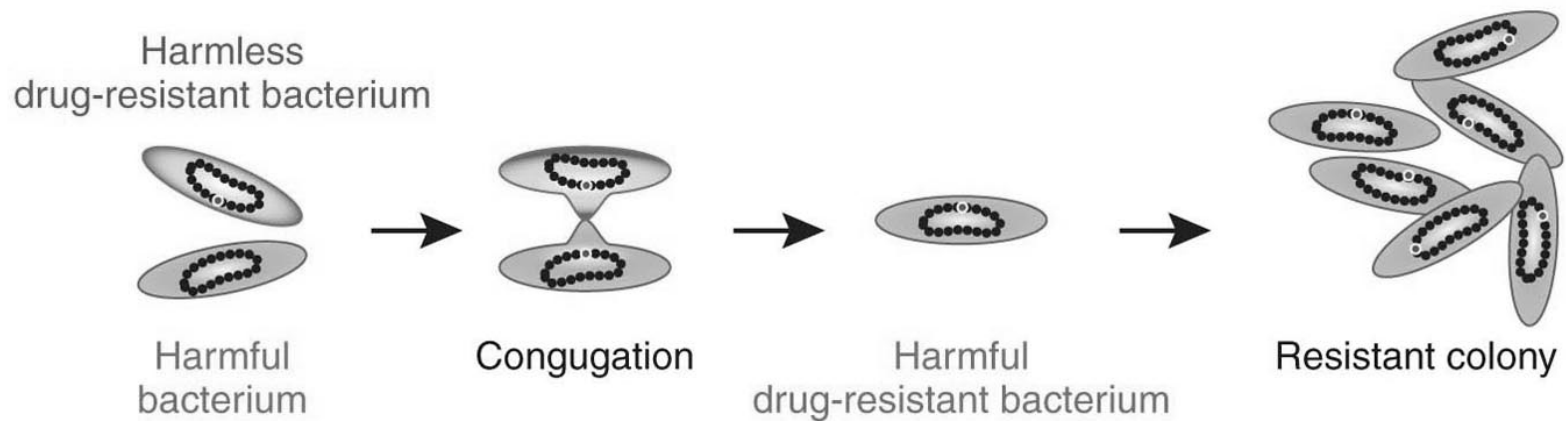
# Antibiotic Resistance

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## (a) Mutation and selection create drug-resistant strains



## (b) Conjugation transfers drug resistance from one strain to another



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# Funding Health Care

- Heaviest burden of illness borne by poorest people who cannot afford a healthy environment or adequate health care.
  - ❖ WHO estimates 90% of all disease burden occurs in developing countries where less than 10% of all health care dollars are spent.
- Increased financial aid to developing countries could reduce the spread of pathogens and might stabilize population growth since parents whose children have a higher survival rate tend to have fewer offspring.

# Toxicology

- Toxicology is the study of poisons and their effects on living systems.
- Dangerous chemicals are divided into two broad categories:
  - ❖ Toxic - poisonous
    - Can be general or very specific. Often harmful even in dilute concentrations.
  - ❖ Hazardous - dangerous
    - Flammable, explosive, irritant, acid, caustic
- Ecotoxicology deals with the interactions, transformation, fate, and effects of natural and synthetic chemicals in the biosphere.

**TABLE 8.2**

**Top 20 Toxic and Hazardous Substances**

<b>Material</b>	<b>Major Sources</b>
1. Arsenic	Treated lumber
2. Lead	Paint, gasoline
3. Mercury	Coal combustion
4. Vinyl chloride	Plastics industrial uses
5. Polychlorinated biphenyls (PCBs)	Electric insulation
6. Benzene	Gasoline, industrial use
7. Cadmium	Batteries
8. Benzo(a)pyrene	Waste incineration
9. Polycyclic aromatic hydrocarbons	Combustion
10. Benzo(b)fluoranthene	Fuels
11. Chloroform	Water purification, industry
12. DDT	Pesticide use
13. Aroclor 1254	Plastics
14. Aroclor 1260	Plastics
15. Trichloroethylene	Solvents
16. Dibenz(a,h)anthracene	Incineration
17. Dieldrin	Pesticides
18. Chromium, hexavalent	Paints, coatings, welding, anticorrosion agents
19. Chlordane	Pesticides
20. Hexachlorobutadiene	Pesticides

**Source:** Data from U.S. Environmental Protection Agency, 2003.

# Toxins

- Allergens - substances that activate the immune system
  - ❖ Antigens - substances that are recognized as foreign by white blood cells and stimulate the production of specific antibodies
    - Other allergens act indirectly by binding to other materials so they become antigenic.
      - Sick Building Syndrome

# Toxins

- Immune System Depressants - pollutants that depress the immune system
- Endocrine Disrupters - disrupt normal hormone functions
  - ❖ Environmental estrogens - environmental contaminants which cause reproductive problems in animals even at very low doses

# Toxins

- Neurotoxins - metabolic poisons that specifically attack nerve cells
  - ❖ Different types act in different ways.
    - Heavy Metals kill nerve cells.
    - Anesthetics and Chlorinated Hydrocarbons disrupt nerve cell membranes.
    - Organophosphates and Carbamates inhibit signal transmission between nerve cells.

# Toxins

- Mutagens - Agents that damage or alter genetic material. Can lead to birth defects or tumors.
- Teratogens - specifically cause abnormalities during embryonic growth and development
  - ❖ Alcohol - Fetal Alcohol Syndrome
- Carcinogens - substances that cause cancer
  - ❖ Cancer is the 2nd leading cause of death.
  - ❖ 1 in 2 males and 1 in 3 females in the U.S. will have cancer in their lifetime.

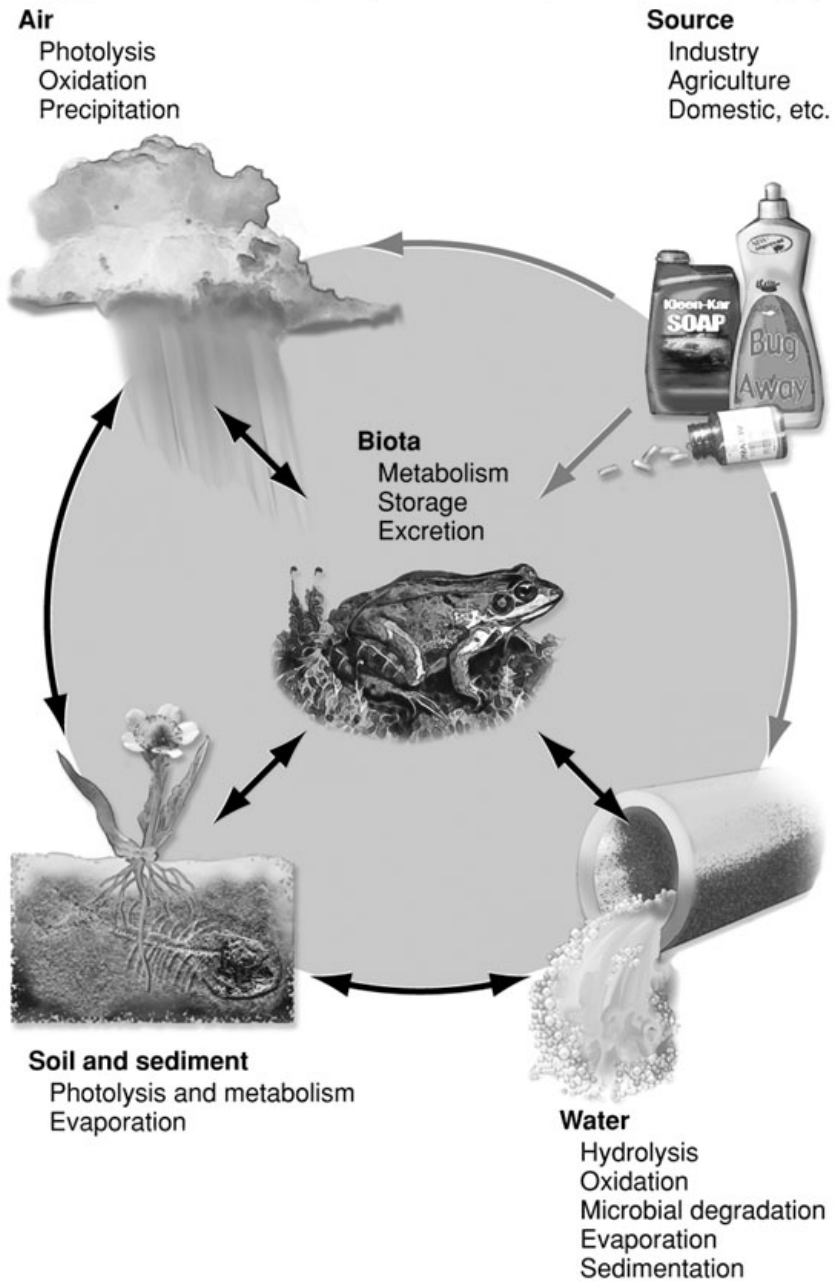
# Diet

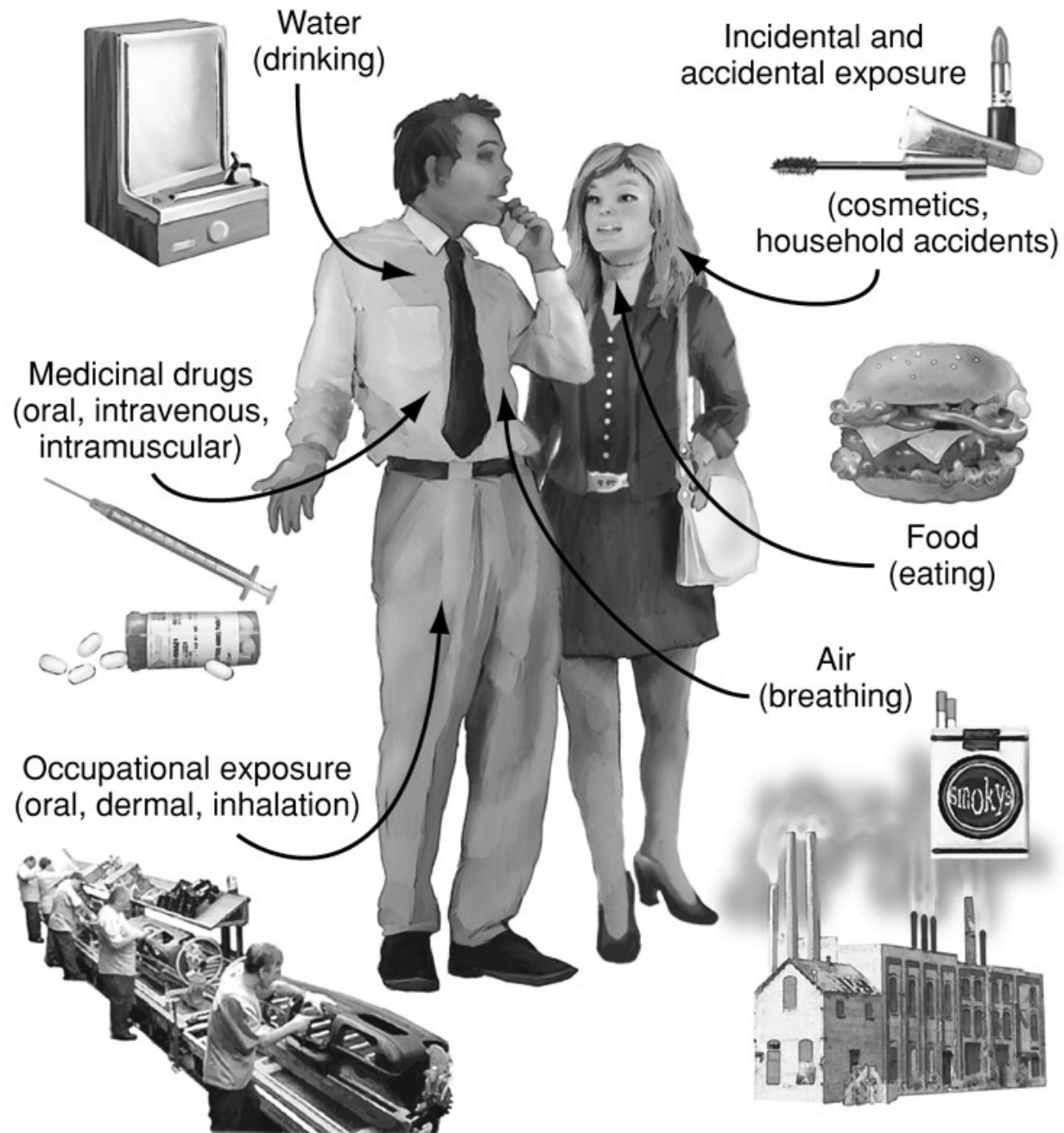
- Correlation between a high fat/high salt diet and cardiovascular disease
- Fruits, vegetables, whole grains, complex carbohydrates, and fiber are beneficial.
- Sixty-percent of all U.S. adults are now considered overweight due to overnutrition.
- U.S. Centers for Disease Control warn one in three U.S. children are at risk of becoming diabetic.



# Movement, Distribution, and Fate of Toxins

- Solubility - one of most important characteristics in determining the movement of a toxin
- Chemicals are divided into two major groups:
  - Those that dissolve more readily in water
  - Those that dissolve more readily in oil
- ❖ Water soluble compounds move rapidly through the environment and have access to cells.
- ❖ Fat soluble compounds need a carrier to move through the environment, but once inside the body they penetrate tissues easily. They are stored in body fat and persist for many years.





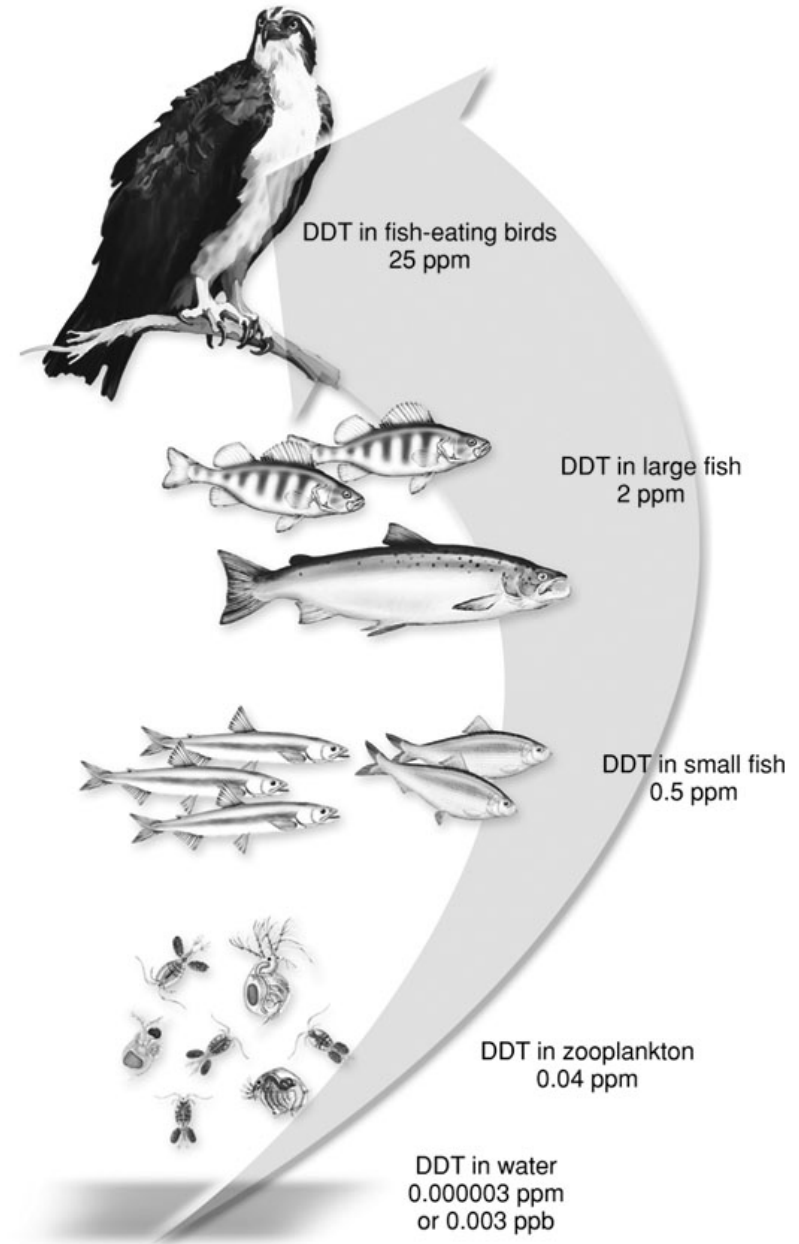
# Exposure and Susceptibility

- Airborne toxins generally cause more ill health than any other exposure.
  - ❖ Lining of lungs easily absorbs toxins.
- Food, water and skin contact are other ways to be exposed to toxins.
- Largest toxin exposure reported in industrial settings
- Condition of organism and timing of exposure also have strong influences on toxicity. Children more vulnerable than adults.

# Bioaccumulation and Biomagnification

- Bioaccumulation - selective absorption and storage of toxins
  - ❖ Dilute toxins in the environment can build to dangerous levels inside tissues.
- Biomagnification - Toxic burden of a large number of organisms at a lower trophic level is accumulated and concentrated by a predator at a higher trophic level. Example: DDT

# Bioaccumulation and Biomagnification



# Persistence

- Some chemical compounds are very unstable and degrade rapidly under most conditions, thus their concentrations decline quickly after release.
- Others are more persistent.
  - ❖ Stability can cause problems as toxins may be stored for a long period of time and spread to unintended victims.

# Examples of Persistent Organic Pollutants

- Flame retardants (PBDE) are now found in humans and other species everywhere in the world. Harm children's reproductive and nervous systems.
- Chemicals used in non-stick plastic coatings (PFOS and PFOA) are infinitely persistent in the environment and found in your blood. Cause liver damage and cancer.
- Phthalates found in plastics mimic estrogen and are linked to reproductive abnormalities and reduced fertility.
- Body burden - accumulated toxins in the body



# Chemical Interactions

- Antagonistic Reaction - one material interferes with the effects, or stimulates the breakdown, of other chemicals
- Additive Reaction - effects of each chemical are added to one another
- Synergistic Reaction - one substance exacerbates the effect of the other
  - ❖ Example: Asbestos exposure increases risk of lung cancer 20X; smoking has same risk. But together, they increase risk 400X.

# Mechanisms for Minimizing Toxic Effects

- Every material can be poisonous under certain conditions.
  - ❖ Most chemicals have a safe threshold under which their effects are insignificant.
- Metabolic Degradation
  - ❖ In mammals, the liver is the primary site of detoxification of both natural and introduced poisons.
    - Sometimes compounds that are harmless can be broken down into products that are harmful.

# Excretion and Repair

- Effects of waste products and environmental toxins reduced by eliminating via excretion.
  - ❖ Breathing
  - ❖ Urine
- Tissues and organs often have mechanisms for damage repair by cellular reproduction.
  - ❖ Any irritating agent can be potentially carcinogenic because the more times that cells divide, the greater the chance that they will have a mistake (mutation) while copying their DNA. This can lead to cancer.

# Measuring Toxicity

- Animal Testing
  - ❖ Most commonly used and widely accepted toxicity test is to expose a population of laboratory animals to measured doses of specific toxins.
- Humanitarian concerns in using animals
- Different individuals have different sensitivities to the same toxin. Should we aim to protect the average person or the most sensitive?

# Complications in Measuring Toxicity

- Unrelated species can react quite differently to the same toxin due to differences in physiology and metabolism.
  - Dose Response Curves not symmetrical
    - LD50 - dose at which 50% of the animal test population dies
- These variations make it difficult to estimate the risk to humans.

# Toxicity Ratings

- Moderate toxin takes about (1) g/kg of body weight to produce a lethal dose.
  - ❖ Very toxic materials require about 10% of that amount.
    - Extremely toxic materials require 1% of that amount.
      - Supertoxic chemicals can be lethal in a dose of a few micrograms (an amount invisible to the naked eye).

# Toxicity Ratings

- Many carcinogens, mutagens, and teratogens are dangerous at levels far below their direct toxic effect because abnormal cell growth exerts a form of biological amplification. One cell mutated by a toxin can form a tumor that kills the individual.

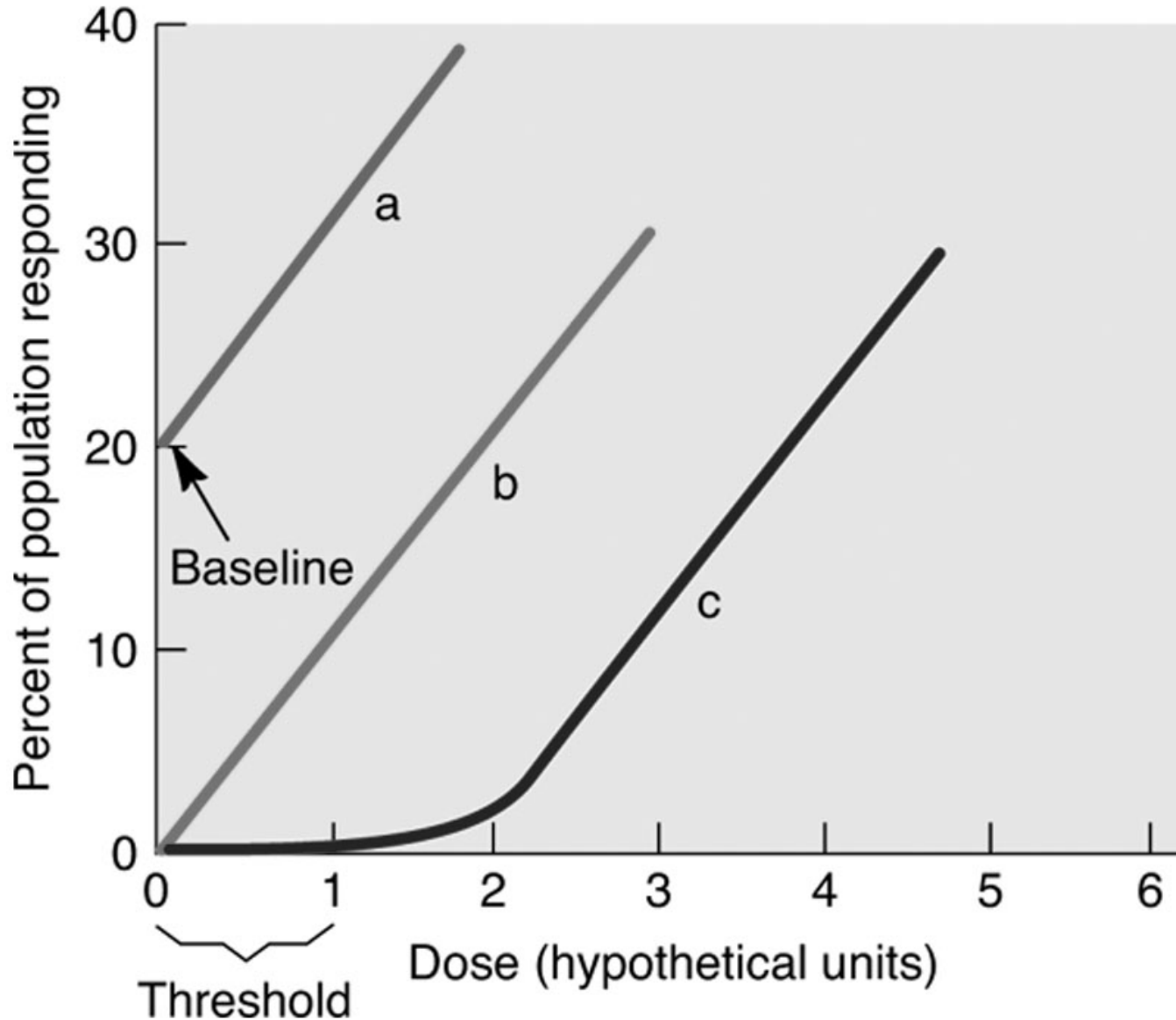
# Acute versus Chronic Doses and Effects

- Acute Effects - caused by a single exposure and results in an immediate health problem
- Chronic Effects - Long-lasting, perhaps permanent. Can be result of single large dose or repeated smaller doses.
  - ❖ Also refer to long-lasting exposures as chronic
  - ❖ Difficult to study the effects of chronic exposure since aging or other diseases may be acting as well.



# Three Possible Dose-Response Curves

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# Thresholds

- The Delaney Clause of the U.S. Food and Drug Act forbids the addition of any amount of known carcinogens to food and drugs.
- This standard was impossible to meet and was replaced in 1996 by a “no reasonable harm” requirement defined as less than one cancer for every million people exposed over a lifetime.

# Risk Assessment and Acceptance

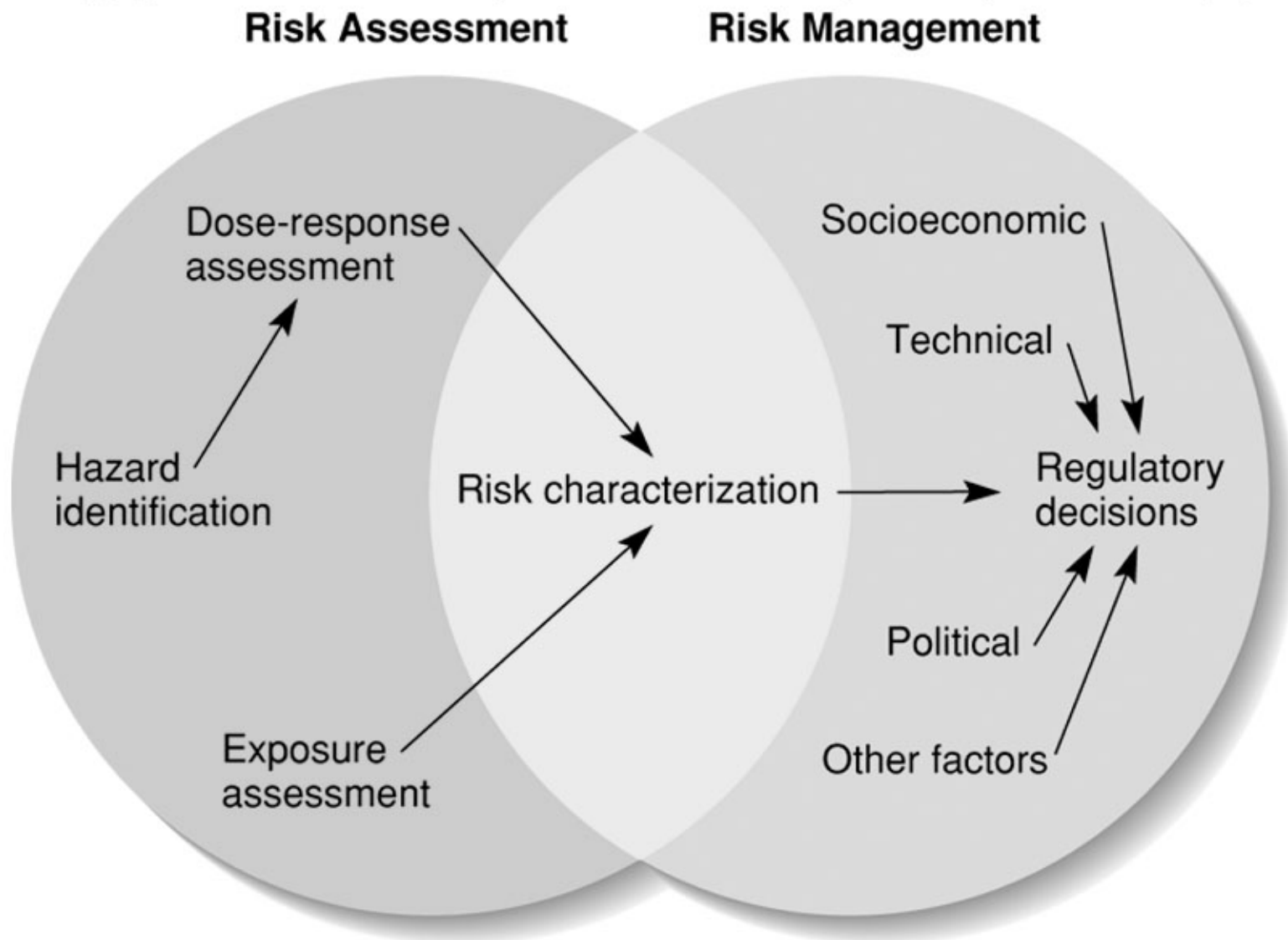
- Risk - possibility of suffering harm or loss
- Risk Assessment - scientific process of estimating the threat that particular hazards pose to human health
  - ❖ Risk Identification
  - ❖ Dose Response Assessment
  - ❖ Exposure Appraisal
  - ❖ Risk Characterization

# Risk Assessment is not Rational

- Interested parties tend to downplay or emphasize risks to suit their agenda.
- We tend to tolerate risks we choose, while objecting to risks that we cannot control.
- Most people do not understand probability.
- Personal experience can be misleading.
- We have an exaggerated view of our own abilities. Most people consider themselves above average drivers.
- News media over-report sensational events and under-report mundane events, skewing our perception of their frequency.
- Irrational fears

# Risk Acceptance

- People will tolerate a high probability of an occurrence if the harm caused is low.
- Great harm is acceptable only at very low levels of frequency.
- For most people, a 1 in 100,000 chance of dying is a threshold for changing behavior.
- Environmental Protection Agency assumes that a risk of 1 in 1 million is acceptable for environmental hazards.
  - ❖ Risk of dying of lung cancer if you smoke is 1 in 4, while risk of drinking water contaminated with the limit of trichloroethylene is 1 in 10 million. Yet many people are focused on the latter.



# Lifetime Chance of Dying in the U.S.

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**TABLE 8.4**

## Lifetime Chances of Dying in the U.S.

Source	Odds (1 in x)
Heart disease	2
Cancer	3
Smoking	4
Lung disease	15
Pneumonia	30
Automobile accident	100
Suicide	100
Falls	200
Firearms	200
Fires	1,000
Airplane accident	5,000
Jumping from high places	6,000
Drowning	10,000
Lightning	56,000
Hornets, wasps, bees	76,000
Dog bite	230,000
Poisonous snakes, spiders	700,000
Botulism	1 million
Falling space debris	5 million
Drinking water with EPA limit of trichloroethylene	10 million

Source: U.S. National Safety Council, 2003.

# Establishing Health Policy

- It is difficult to separate the effects of multiple hazards and evaluate their risks accurately, especially when exposures are near the threshold of measurement and response.
- In setting standards, should consider:
  - ❖ combined effects of exposure
  - ❖ different sensitivities
  - ❖ effects of chronic as well as acute exposure
- Not reasonable to be protected from every contaminant no matter how small the risk
- We must consider the effects on other organisms that maintain our environment.